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ABSTRACT

A mathematical model was used to consider alternative request routing policies for use in the Illinois Library and Information Network. Given data on interlibrary loan demands, the probability of request success, processing and delivery times for various libraries, and a network request routing policy, the model predicted the probability of satisfying a request, the average delay in receipt of the desired item, the cost, and processing loads. Comparing resource centers in the network revealed that Illinois State Library (ISU) and University of Illinois Libraries (UOI) are superior to Chicago Public Library (CPL) and Southern Illinois University (SIU) in terms of probability of request success and average processing times. When CPL and SIU were removed from the model, performance was not significantly degraded. While available data were too limited to make a strong recommendation for removing CPL and SIU from the network, a careful data collection procedure should be pursued to study the network and perhaps at some time in the future to automate data collection. (CH)

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A MATHEMATICAL MODEL

OF THE

ILLINOIS INTERLIBRARY LOAN NETWORK

Project Report No. 3

Submitted to

Illinois State Library

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FOREWORD

This is the third in a series of reports resulting from a research grant to the Coordinated Science Laboratory of the University of Illinois at Urbana-Champaign. The sponsor of the grant is the Illinois State Library under the Illinois Program for Title I of the Federal Library Services and Construction Act.

Previous reports can be purchased in hardcopy or microfiche from ERIC Document Reproduction Service, Computer Microfilm International Corp. (CMIC), 2020 14th Street North, Arlington, Virginia 22201.

1. W. B. Rouse, J. L. Divilbiss, and S. H. Rouse, A Mathematical Model of the Illinois Interlibrary Loan Network: Project Report No. 1, Coordinated Science Laboratory Report No. T-14, University of Illinois at Urbana-Champaign, November 1974, ERIC No. ED 101 667.

   Includes a review of the literature on interlibrary loan networks, a flow chart description of the Illinois network, a review of methodologies appropriate to modeling networks, an initial model, and discussion of alternative computer and communication technologies.

2. W. B. Rouse, J. L. Divilbiss, and S. H. Rouse, A Mathematical Model of the Illinois Interlibrary Loan Network: Project Report No. 2, Coordinated Science Laboratory Report No. T-16, University of Illinois at Urbana-Champaign, March 1975, ERIC No. ED 107 287.

   Includes a derivation of the mathematical model (version no. 2) and its applications to a hypothetical network so as to illustrate various policy issues. A summary of the User's Manual for the interactive program of the model is also included.

TABLE OF CONTENTS

I. INTRODUCTION AND SUMMARY

The purpose of this report is to consider alternative request routing policies for use in the Illinois Library and Information Network. In pursuit of this goal, we have employed the mathematical formulation developed in our earlier reports.* Before summarizing the results of our analyses, let us briefly review what the mathematical model does.

Given data on interlibrary loan demands throughout a network; a characterization of the probabilities of success, processing times, and delivery times for the various resource libraries in the network; and a network request routing policy, the mathematical model will predict probability of satisfying a request, average delay from initiation of the request until receipt of the desired item by the requestor, average total and unit costs, and average processing loads throughout the network. These predictions are broken down by request class and resource library as well as being summarized across request classes and libraries.

Four data files are necessary as input to the model and a substantial portion of this report deals with the development of the data for these four files. Several distinct data sets were available and considerable discussion is devoted to considering the consistency of these data sets and to combining them where appropriate. We obtained the necessary data files but not without the realization that our data is very limited and thus, our conclusions will have to be interpreted as tentative and requiring further substantiation or perhaps refutation.

*See the Foreword for a note on our earlier reports.

With our data files obtained, we then consider several approaches to policy formulation, several of which lead to similar results. The result is basically that ISL and UOI are very much superior to CPL and SIU in terms of probability of success and average processing times and, regardless of how you tradeoff probability of success and average delay, the Centers of first resort should always be ISL and UOI. Further, the superiority of ISL and UOI can <u>not</u> be solely attributed to the availability of film catalogs for those Centers or to the fact that CPL and SIU must deal more frequently with referred requests. As a public library in a network where public library requests dominate, CPL appears to have an availability problem. In other words, the local clientele of CPL are requesting the same items requested by network clientele. SIU has this problem to a lesser extent, but also has the weakest collection of the four Centers. On the other hand, ISL and UOI appear to have local clientele that request different types of items than those requested by the network clientele.

With these results in mind, we analyzed the impact on network performance of removing CPL and/or SIU from the network. Results indicate that the network performance is not significantly degraded by removing both CPL and SIU. Perhaps any difficulties could be avoided by making either or both of them into Special Resource Libraries or Systems (which CPL already is). While the available data is too limited to make a strong recommendation for removing CPL and SIU from the network, the data is sufficient to warrant a careful data collection effort to enable a sound decision to be made.

Our strongest recommendation is that data collection procedures be developed that allow accumulation of sufficient sample sizes to enable firm

conclusions to be drawn from the data. Standardized methods that allow comparisons between data collection periods are necessary. With the current TWX network and various implementations of computer technology now being studied, it may be possible to automate data collection. This would seem to be a most attractive possibility.

II. INPUT DATA AND MODEL PARAMETERS

A. INTRODUCTION

In this section, we want to first review the input data required by the ILLINET model. Then, we will consider the available data sets from which we might draw the required input data. Finally, we will discuss the specific data analyses performed and the resulting input data for the model. Since we have to perform numerous manipulations of the raw data to obtain the input data for the model, it is perhaps more appropriate to refer to this input data as the model parameters. Thus, we will use the terms "input data" and "model parameters" interchangeably.

B. REVIEW OF DATA REQUIREMENTS

The input data required by the model can be categorized into four classes: demands, probabilities of success, processing times, and delivery time. We will now consider each of these classes in detail.

DEMANDS

The <u>average</u> number of requests per day (or any other convenient unit of time) generated* by System k in request class j will be denoted by λ_{jk}.

A System is any request-generating organization that can deal directly with the Centers. Thus, besides the 18 Systems that we normally consider, we can consider non-System requests (e.g., those from large academic libraries) to originate in pseudo-Systems which, as far as the model is concerned, operate in a manner similar to that of the basic 18 Systems.

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*Requests sent to the Center level of the network

Request class can represent subject area, type of request (e.g., document or information), type of requestor, type of initiating library, etc. Of course, a detailed classification of requests will require a detailed data collection effort to obtain estimates of λ_{jk}. As the range of j increases, the overall sample size will have to increase if the accuracy of each λ_{jk} estimate is to be maintained.

PROBABILITY OF SUCCESS

The probability that a request in class j is satisfied by Center i will be denoted by p_{ij}. Recalling our model of the internal operation of each Center (Project Report No. 2, pp. 32-38), p_{ij} is related to the six probabilities tabulated below. Given estimates of these six probabilities (which, in general, vary with i and j), one can calculate p_{ij}.

Probability	Definition
c_{ij}	probability of a request being received with appropriate <u>call number</u>
o_{ij}	probability of the desired document being <u>owned</u> given that the request is verified
a_{ij}	probability of the desired document being <u>available</u> given that it is owned
v_{ij}	probability that a request has been <u>verified</u> previous to its being received
f_{ij}	probability that an unverified request will be <u>forwarded</u> without an attempt to verify it
s_{ij}	probability of the <u>successful verification</u> of a request that was unverified when received

We might want to consider defining p_{ij} as p_{ijk} where k varies with referral number. This would allow for the possibility of referred requests being intrinsically more difficult to satisfy. In other words, the "easy" requests are satisfied when they initially enter the Center level of the network while the "hard" requests are referred to other Centers. This also requires that the six probabilities tabulated above be defined by referral number. This presents no difficulties for the model, but may result in data collection problems. We will discuss this issue at the end of Section II-B.

PROCESSING TIMES

The average processing time (time waiting for service plus time in service) of a request at process* k of Center i will be denoted ω_{ik}. Based on queueing theory concepts, we know that ω_{ik} is related to the average demand on process k and the average rate at which requests can be serviced at process k.

The average demand on process k of center i can be determined using λ_{jk}, p_{ij}, the six probabilities noted above, and the network operating policy.

It is unlikely that the average service rate at process k of Center i would be directly measured since this would require detailed observation of the process. Instead, ω_{ik} can be estimated via a least-squares fit and the average service rate then calculated. The method of estimating ω_{ik} will be discussed in Section II-D.

*This six processes at a Center are: in-processing of request, search, obtain, out-processing of document or information, verify, and out-processing of unsatisfied request (Project Report No. 2, p. 33).

DELIVERY TIMES

The average number of days to deliver a document or information to System k from Center i will be denoted by t_{ik}. This definition could possibly be expanded to t_{ijk} and thus be sensitive to request class j. This would allow, for example, for different average delivery times for documents and information. While such an extension of the delivery time definition would require only a minor modification of the model, it also has implications for data collection in that additional information would then be necessary.

A COMMENT ON DATA REQUIREMENTS

Ideally, one would like to have many request classes to reflect subject areas, types of requests, types of initiating libraries, modes of delivery, etc. Also, one would like the probability of success to be sensitive to referral number and average delivery times to be sensitive to request class. While, at the moment, the ILLINET model does incorporate these latter features, they are minor modifications that will surely be implemented in the future.

The difficulty presented by adoption of all of these features is in data collection. An example will serve to emphasize this point. Consider the problem of estimating the probabilities of success defined earlier. With 4 Centers and 40 request classes*, if we choose to let the probabilities be sensitive to referral number and we require data from N requests to make each estimate of probability p_{ijk}, then data for at least 640 N requests would be needed. If we let N be 50, which is not a particularly large sample, then data for at least 32,000 requests would be needed. Further, since

*40 was chosen because two of the data sets which we will employ in later analyses include 40 request classes.

every request does not go through every process in a Center, a larger sample would be necessary to estimate all six probabilities associated with Center processing. This increase would have to at least account for the difference in processing of satisfied and unsatisfied requests. If we assume an overall probability of satisfaction of 0.50, our minimum sample size becomes 64,000 requests. To put this number in context, the two available data sets with which we will be estimating probabilities of success include 721 and 1044 requests, respectively. Thus, we will have to compromise on number of request classes, number of data points per estimate, etc.

C. AVAILABLE DATA SETS

We are going to employ four sources of data in estimating model parameters. These sources include Illinois State Library (ISL) yearly statistics, two surveys by the Library Research Center (LRC), and a postal delivery time study performed by ISL. At this point, we will simply describe these data sets. In the section following this, we will discuss estimating model parameters.

ISL YEARLY STATISTICS

This data set* summarizes the activity of the network for the period July 1974 through June 1975. One portion of this data set summarizes activity at the System level of the network while another portion summarizes activity at the Center level of the network.

From the Systems data, we can determine the distribution of public library requests among Systems while the data for Centers gives us the distribution of all requests among Centers as well as the number of requests received with call numbers and the number of requests that are

*Obtained from W. DeJohn in October 1975.

filled, not filled, referred and the reasons for lack of success in satisfying a request. This data is aggregated across request classes.

LRC NETWORK SAMPLE

For this sample, the network libraries were stratified by type: public, academic, special, and correctional. A random sample was drawn from each type including 50 public, 20 academic, 20 special, and 7 correctional while the population included 509 public, 100 academic, 82 special, and 21 correctional. The sample was drawn without regard to library size or geographical area.

All requests initiated by the chosen libraries in February 1975 were followed as they proceeded through the network. 586 of these requests made it to the Center level of the network and, via referral, resulted in the processing of 721 requests by the Centers.

From this sample, we can determine parameters relating to individual Centers and their success in processing requests in the various request classes. The six probabilities associated with Center processing can be estimated as well as the processing times within each subprocess (i.e., search, verify, etc.). Requests are categorized into 40 classes and are aggregated across initiating Systems.

LRC CENTER SAMPLE

This sample includes 5% of all requests processed by each Center during February 1975. (For ISL, the sample was 7½% of three weeks of February's requests. This resulted in 1044 requests. (It should be noted that this does not necessarily represent 1044 unique requests as referral could easily cause a single request to show up in more than one Center's sample.) Requests are also aggregated into 40 classes in the sample but they are not aggregated across systems.

We can employ this sample in a manner similar to the network sample. In some cases, parameter estimates can be based on both samples while, in other cases, inherent differences in the samples pre ent this aggregation. We will pursue this topic further when we discuss data analysis.

ISL POSTAL DELIVERY TIME STUDY

This data set* includes the average postal delivery time (in days) between ISL and 13 of the Systems. These averages, as well as the sample sizes by System, can be used to estimate postal delivery times throughout the state.

SOME COMPARISONS

Two reasons have motivated out choice to employ two data sets beyond the two LRC samples. The ISL yearly statistics allow corroboration for parameter estimates based on the LRC samples. The ISL postal study serves as a basis for estimating postal delivery times throughout the state. It might be desirable to have a single sample to employ in estimation of all parameters. However, comparing different samples does help to corroborate sampling schemes. We will consider this point in more detail in the following discussion of data analysis.

D. DATA ANALYSIS

We will now consider how model parameters can be estimated using the four data sets discussed above. The parameters will be discussed in the categories noted earlier: demands, probabilities of success, service times, and delivery times.

*Obtained from ISL memo by B. Halcli dated December 12, 1973.

To process the two LRC samples, it was necessary to make several assumptions. These are detailed in the Appendix.

DEMANDS

To estimate λ_{jk} (the average demand generated by System k in request class j), we will rely on three of our four data sets. The ISL yearly statistics will be compared with parameter estimates based on the two LRC samples. The resulting parameter estimates will be based on the data sample that produces estimates most consistent with all three sources of information.

First, we will consider the yearly and average daily demands on the four Centers. Using the ISL yearly statistics, the results in Tables I and II were obtained. To estimate how these requests were distributed among Systems, we first must recall that not all requests are generated by the basic 18 Systems. Those requests coming from large academic libraries (collections in excess of 200,000 volumes) are not processed by any of the basic 18 Systems. To determine how requests are distributed among library types, we used the two LRC samples to obtain Tables III. We can see that Tables IIIA and IIIB differ substantially in their estimates of the percent of requests from large academic libraries (LAC)*. Which estimate should we employ?

Resorting to the ISL yearly statistics for System processing of public library requests, we found that public library requests resulted in 72,621 titles being sent to requestors. This accounts for 75.5% of all titles sent (96,149) by the Centers during 1974-1975. If we use the estimate

*Considering the differences in sampling procedures utilized for the two LRC samples, this result is not unexpected. As long as we are aware of it, this discrepancy does not hinder our analyses.

CENTER	INITIAL REQUESTS	REFERRAL REQUESTS	TOTAL	FILLED	NOT FILLED
CPL	31,624	7,860	39,484	5,929	33,555
ISL	68,750	2,342	71,092	54,959	16,133
UOI	43,861	11,599	55,460	28,199	27,261
SIU	12,954	15,699	28,653	7,994	20,659
TOTAL	157,189	37,500	194,689	97,081	97,608

TABLE I: Yearly Demand on Centers

CENTER	REQUESTS PER DAY[a]	PERCENT OF TOTAL	PERCENT FILLED
CPL	157.9	20%	15%
ISL	284.4	36%	77%
UOI	221.8	28%	51%
SIU	114.6	15%	28%
TOTAL	778.8	99%[b]	62%[c]

a Assuming 250 days of operation per year.

b Special Resource Libraries process 1% of the overall demand.

c Based on unique requests. Otherwise, entry is 50%.

TABLE II: Average Daily Demand on Centers

NETWORK SAMPLE

	PUB NO.	PUB %	LAC NO.	LAC %	SAC NO.	SAC %	SPC NO.	SPC %	COR NO.	COR %	TOT NO.	TOT %
CPL	52	43.33	0	0.00	63	52.50	1	0.83	4	3.33	120	16.64
ISL	194	65.32	0	0.00	76	25.59	2	0.67	25	8.42	297	41.19
UOI	96	42.06	2	0.86	78	33.48	53	22.75	2	0.86	233	32.32
SIU	54	76.06	0	0.00	15	21.13	1	1.41	1	1.41	71	9.85
TOT	398	55.20	2	0.28	232	32.18	57	7.91	32	4.44	721	100.00

TABLE III A: Distribution of Requests Among Local Library Types (Network Sample)

CENTER SAMPLE

	PUB NO.	PUB %	LAC NO.	LAC %	SAC NO.	SAC %	SPC NO.	SPC %	COR NO.	COR %	SYS NO.	SYS %	TOT NO.	TOT %
CPL	127	78.88	4	2.48	20	12.42	9	5.59	1	0.62	0	0.00	161	15.78
ISL	304	88.37	3	0.87	23	6.69	5	1.45	9	2.62	0	0.00	344	33.73
UOI	194	63.61	38	12.46	40	13.11	26	8.52	1	0.33	6	1.97	305	29.90
SIU	154	73.33	22	10.48	17	8.10	14	6.67	0	0.00	3	1.43	210	20.59
TOT	779	76.37	67	6.57	100	9.80	54	5.29	11	1.08	9	0.88	1020	100.00

TABLE III B: Distribution of Requests Among Local Library Types (Center Sample)

from Table IIIA, we find that 55.2% of the requests (%PUB) obtain 75.5% of all titles sent. This can only be true if 44.8% of the requests (%non-PUB) experience very low probabilities of success. A later analysis will show that this is unlikely. Thus, we must conclude that the estimate from Table IIIB should be employed in further analyses.

Using the LRC Center sample, we determined distribution of requests among Systems shown in the left columns of Table IV. The LA percentage* increased slightly over that in Table IIIB because some non-LA requests were without System codes.

The "titles received" entries of the ISL yearly statistics for Systems were also used to estimate the distribution of requests among Systems. Three assumptions are required to use the ISL yearly statistics for this purpose. First, we assume that the percent of total public library requests generated by a specific System is indicative of the percent of all requests generated by that System. Second, we assume that probability of satisfaction at the Center level of the network is independent of the specific System generating the request. Third, we assume that the ratio of titles sent to requests filled (by the Center level of the network) is independent of the specific System generating the request. Using these assumptions, the distribution of requests among Systems was determined and is shown in the right columns of Table IV.

The two sets of estimates are similar in magnitudes but have definite differences. This poses a dilemma. The LRC data includes a one-month's sample while the ISL data is a year's data. On the other

*A 19th System was defined as including all large academic libraries. We could define each large academic library as a System and thus, be more accurate in our operational description. However, the small number of requests generated by large academic libraries does not appear to justify such detail.

LRC Center Sample		ISL Yearly Statistics	
SYSTEM	PERCENT	SYSTEM	PERCENT
BO	5.73	BO	4.76
CP	1.38	CP	0.18
CB	6.15	CB	3.97
CT	3.08	CT	2.50
DU	5.83	DU	6.46
GR	1.38	GR	2.33
IV	5.62	IV	3.05
KK	4.03	KK	6.09
LA*	7.10	LA*	6.57
LC	2.55	LC	4.88
LT	4.14	LT	4.26
NS	16.12	NS	13.20
NI	3.82	NI	6.10
RB	1.06	RB	1.42
RP	4.98	RP	5.20
SH	3.82	SH	6.20
SR	3.29	SR	4.96
SU	16.44	SU	13.88
WI	3.50	WI	3.98

*Large Academic Libraries

TABLE IV: Distribution of Requests Among Systems

hand, we required several assumptions to pull the desired estimates out of the ISL data. To resolve this issue, we will continue, as we have throughout this report, to utilize estimates based on LRC data and include estimates based on ISL data for comparison purposes only.

The two LRC samples were used to estimate the distribution of requests among subject areas. (The 40 subject classes are those chosen by LRC.) The results are shown in Tables V. If we assume that the subject class of a particular request is independent of the type of library initiating that request, then Tables VA and VB can be merged. However, even when the tables are merged, some classes have very few requests. Since we plan to further subdivide the subject distribution by Center and perhaps by referral number, we will have to decrease the number of subject classes to maintain the accuracy of our estimate of the distribution of requests among subject classes.

We decided to reclassify the requests into the 10 Dewey classification ranges (i.e., 000-099, 100-199, etc.). Since the LRC network sample included call numbers with many requests, this reclassification would appear easy. Unfortunately however, no fixed procedure was used by LRC in determining one of the 40 request classes from a request's call number. In an attempt to alleviate this difficulty, the network sample was sorted by request class and the call numbers within each class printed out. Inspection of the results led to the reclassification summarized in Table VI. Using this scheme yielded the results in Table VII. 375 of the 422 requests with legitimate call numbers were reclassified correctly. A reclassification scheme that will surpass this 89% accuracy is not evident.

Using the scheme discussed above, Tables V become Tables VIII. The two samples are combined in Table IX. Ranges 0, 1, 2, 4, and 5 have fairly

NETWORK SAMPLE

SUBJ CODE	NO. REQ.	% REQ.	NO. FILD.	NO. UNFILD	% FILD	SUBJ CODE	NO. REQ.	% REQ.	NO. FILD	NO. UNFILD	% FILD
1	22	3.15	16	6	72.73	21	29	4.15	21	8	72.41
2	43	6.16	34	9	79.07	22	30	4.30	17	13	56.67
3	40	5.73	26	14	65.00	23	5	0.72	5	0	100.00
4	39	5.59	33	6	84.62	24	25	3.58	4	21	16.00
5	14	2.01	8	6	57.14	25	20	2.87	14	6	70.00
6	10	1.43	5	5	50.00	26	2	0.29	2	0	100.00
7	18	2.58	17	1	94.44	27	15	2.15	10	5	66.67
8	21	3.01	15	6	71.43	28	8	1.15	5	3	62.50
9	6	0.86	6	0	100.00	29	1	0.14	1	0	100.00
10	45	6.45	33	12	73.33	30	17	2.44	9	8	52.94
11	13	1.86	11	2	84.62	31	30	4.30	22	8	73.33
12	2	0.29	2	0	100.00	32	5	0.72	4	1	80.00
13	2	0.29	2	0	100.00	33	39	5.59	32	7	82.05
14	13	1.86	12	1	92.31	34	69	9.89	48	21	69.57
15	0	0.00	0	0	0.00	35	4	0.57	2	2	50.00
16	5	0.72	2	3	40.00	36	28	4.01	15	13	53.57
17	21	3.01	16	5	76.19	37	8	1.15	8	0	100.00
18	3	0.43	0	3	0.00	38	9	1.29	9	0	100.00
19	25	3.58	20	5	80.00	39	0	0.00	0	0	0.00
20	12	1.72	8	4	66.67	40	0	0.00	0	0	0.00
TOTAL							698		494	204	70.77

(Note: 23 requests had no subject code.)

TABLE V A: Distribution of Requests Among Subject Classes (Network Sample)

CENTER SAMPLE

SUBJ CODE	NO. REQ.	% REQ.	NO. FILD	NO. UNFILD	% FILD	SUBJ CODE	NO. REQ.	% REQ.	NO. FILD	NO. UNFILD	% FILD
1	24	2.51	14	10	58.33	21	52	5.43	23	29	44.23
2	70	7.31	35	35	50.00	22	43	4.49	15	28	34.88
3	47	4.91	24	23	51.06	23	20	2.09	8	12	40.00
4	35	3.65	22	13	62.86	24	15	1.57	5	10	33.33
5	14	1.46	8	6	57.14	25	40	4.18	24	16	60.00
6	19	1.98	14	5	73.68	26	9	0.94	5	4	55.56
7	17	1.77	11	6	64.71	27	10	1.04	5	5	50.00
8	52	5.43	26	26	50.00	28	35	3.65	13	22	37.14
9	13	1.36	3	10	23.08	29	13	1.36	5	8	38.46
10	48	5.01	31	17	64.58	30	19	1.98	8	11	42.11
11	12	1.25	9	3	75.00	31	39	4.07	25	14	64.10
12	5	0.52	2	3	40.00	32	12	1.25	9	3	75.00
13	2	0.21	2	0	100.00	33	51	5.32	25	26	49.02
14	9	0.94	6	3	66.67	34	53	5.53	23	30	43.40
15	1	0.10	1	0	100.00	35	16	1.67	13	3	81.25
16	4	0.42	4	0	100.00	36	47	4.91	28	19	59.57
17	13	1.36	6	7	46.15	37	13	1.36	7	6	53.85
18	8	0.84	6	2	75.00	38	18	1.88	10	8	55.56
19	34	3.55	23	11	67.65	39	0	0.00	0	0	0.00
20	26	2.71	11	15	42.31	40	0	0.00	0	0	0.00
TOTAL							958		509	449	53.13

(Note: 86 requests had no subject code)

TABLE V B: Distribution of Requests Among Subject Classes (Center Sample)

CALL NO. RANGE	LRC SUBJECT CATEGORIES*
000-099	1
100-199	2
200-299	3
300-399	4 - 11
400-499	12
500-599	13 - 16, 19
600-699	17, 18, 20 - 24
700-799	25 - 30
800-899	31, 32, 34, 35, FIC, JFIC
900-999	33, 36 - 38, BIOG

*There were no requests in categories 39 and 40.

TABLE VI: Scheme for Reclassifying Request Subject Areas

RANGE	NO. CORRECT	NO. INCORRECT	NO CLASS.	ERRORS
0	15	0	4	1
1	27	5	6	0
2	16	7	7	0
3	67	6	66	0
4	1	0	0	1
5	25	7	11	0
6	60	9	30	0
7	35	4	9	0
8	80	1	8	0
9	49	8	12	0
TOTAL	375	47	153	2

NO SUBJ. CODE = 9

TABLE VII: Results of Reclassifying Request Subject Areas (Network Sample)

NETWORK SAMPLE

RANGE	NO. REQ.	% REQ.	NO. FILD	NO. UNFILD	% FILD
0	22	3.15	16	6	72.73
1	43	6.16	34	9	79.07
2	40	5.73	26	14	65.00
3	166	23.78	128	38	77.11
4	2	0.29	2	0	100.00
5	45	6.45	36	9	80.00
6	125	17.91	71	54	56.80
7	63	9.03	41	22	65.08
8	108	15.47	76	32	70.37
9	84	12.03	64	20	76.19
TOTAL	698		494	204	70.77

NO. WITHOUT SUBJ. CODE= 23

TABLE VIII A: Distribution of Requests Among Dewey Subject Classes (Network Sample)

CENTER SAMPLE

RANGE	NO. REQ.	% REQ.	NO. FILD	NO. UNFILD	% FILD
0	24	2.51	14	10	58.33
1	70	7.31	35	35	50.00
2	47	4.91	24	23	51.06
3	210	21.92	124	86	59.05
4	5	0.52	2	3	40.00
5	50	5.22	36	14	72.00
6	177	18.48	74	103	41.81
7	126	13.15	60	66	47.62
8	120	12.53	70	50	58.33
9	129	13.47	70	59	54.26
TOTAL	958		509	449	53.13

NO. WITHOUT SUBJ. CODE= 86

TABLE VIII B: Distribution of Requests Among Dewey Subject Classes (Center Sample)

RANGE	NO. REQ.	% REQ.	NO. FILD	NO. UNFILD	% FILD
0	46	2.78	30	16	65.22
1	113	6.82	69	44	61.06
2	87	5.25	50	37	57.47
3	376	22.71	252	124	67.02
4	7	0.42	4	3	57.14
5	95	5.74	72	23	75.79
6	302	18.24	145	157	48.01
7	189	11.41	101	88	53.44
8	228	13.77	146	82	64.04
9	213	12.86	134	79	62.91
TOTAL	1656		1003	653	60.57

NO. WITHOUT SUBJ. CODE= 109

TABLE IX: Distribution of Requests Among Dewey Subject Classes (Combined Samples)

small sample sizes which might make grouping of classes desirable. However, a classification scheme based on the 10 Dewey ranges is attractive from the point of view of implementing results in the sense of the request routing policies to be recommended later in this report. Thus, we will retain the 10 ranges.

The center sample was employed to estimate the average daily demand emanating from each System in each subject class. Since the sample includes 5% of twenty days' activity, it can be directly interpreted as the average daily demand. The results are shown in Table XA.

For comparison purposes, we also used the ISL yearly statistics to estimate the average daily demand. Recall from Table II that Centers process requests at an average rate of 778.8 per day. Combining this figure with the results in the right column of Table IV and those in Table IX*, yields the distribution of requests shown in Table XB. The results are comparable with both approaches. As before we will employ the estimates based on the LRC data in all further analyses.

The estimates in Table XA provide the λ_{jk} parameters discussed earlier. This table is almost identical in format to the demand data file accessed by the model from disk.

PROBABILITIES OF SUCCESS

Recall that the probability that a request in class j is satisfied by Center i (denoted p_{ij}) can be derived from the six constituent probabilities c_{ij}, o_{ij}, a_{ij}, v_{ij}, f_{ij}, and s_{ij}. For the moment, we will aggregate across request classes and thereby simplify the discussion.

*It is assumed that the subject distribution is independent of Systems.

RANGE (SUBJECT CLASSIFICATION)

SYS	0	1	2	3	4	5	6	7	8	9	TOTAL
BU	2	2	1	13	0	4	15	3	2	5	47
CP	0	1	2	1	0	0	4	5	0	0	13
CH	2	2	1	9	1	3	10	7	5	9	49
CT	0	2	1	4	0	0	7	3	3	5	25
DU	1	5	4	6	3	1	7	13	5	6	51
GR	1	0	0	2	0	3	1	1	3	2	13
IV	4	3	4	9	0	1	6	[illegible]	6	8	50
KY	0	4	2	6	0	0	4	11	9	2	38
LA*	4	2	6	19	0	7	9	0	4	7	58
LC	0	1	1	6	0	0	8	1	1	3	21
LT	[illegible]	2	4	2	0	0	10	5	7	4	34
NS	2	12	10	34	0	7	18	17	16	18	134
NJ	0	3	0	8	0	1	5	4	3	8	32
RB	0	0	0	3	0	0	2	2	0	2	9
RP	2	3	1	13	0	3	4	5	7	6	44
SH	0	2	1	6	0	1	5	3	8	10	36
SR	0	1	0	4	1	2	8	2	5	7	30
SU	3	17	7	23	0	8	26	[illegible]	22	13	142
WI	0	1	1	11	0	1	6	1	5	8	34
TOTAL	24	63	46	179	5	42	155	165	111	123	860

NO. WITHOUT SYSTEM CODE = 98
NO. WITHOUT SUBJECT CODE = 86

* Large Academic Libraries

TABLE XA: Distribution of Average Daily Demand (Requests/Day) Among Systems and Subject Classes (Center Sample)

RANGE(SUBJECT CLASSIFICATION)

SYS	0	1	2	3	4	5	6	7	8	9	TOTAL
BU	1	3	2	8	0	2	7	4	5	5	37
CE	0	0	0	0	0	0	0	0	0	0	0
CB	1	2	2	7	0	2	6	4	4	4	32
CI	1	1	1	4	0	1	4	2	3	3	20
DU	1	3	3	11	0	3	9	6	7	7	50
GR	1	1	1	4	0	1	3	2	2	2	17
IV	1	2	1	5	0	1	4	3	3	3	23
KN	1	3	3	11	0	3	9	5	7	6	48
LA*	1	3	3	12	0	3	9	6	7	7	51
LC	1	3	2	9	0	2	7	4	5	5	38
LI	1	2	2	8	0	2	6	4	5	4	34
OS	2	7	5	23	0	6	19	12	14	13	102
NI	1	3	3	11	0	3	9	5	7	6	48
RB	0	1	1	2	0	1	2	1	2	1	11
RP	1	3	2	9	0	2	7	5	6	5	40
SH	1	3	3	11	0	3	9	6	7	6	49
SN	1	3	2	9	0	2	7	4	5	5	38
SU	2	7	6	25	0	6	20	12	15	14	108
WI	1	2	2	7	0	2	6	4	4	4	32
TOTAL	21	52	44	176	0	45	143	89	108	100	778

*Large Academic Libraries

TABLE XB: Distribution of Average Daily Demand (Requests/Day) Among Systems and Subject Classes (ISL Yearly Statistics).

Tables XI show how the probability of success varies with Center and re·ferral number. The most striking difference between Table XIA and XIB is found in overall probability of success estimates (in the lower right-hand corner of each table). The network sample yields an estimate of 68.6% while the center sample yields an estimate of 49.5%. ISL's yearly statistics show 50.0% for this overall probability. Once again, we find ourselves supporting the use of the center sample (Table XIB) as opposed to the network sample. To explain why the network sample overestimates probability of success, recall that non-public libraries are overrepresented in the network sample. If requests from non-public libraries experience more success than those from public libraries, the difference in overall probabilities of success might easily be explained. This conclusion also supports our earlier decision to use the center sample as a basis for estimating the distribution of requests among library types.

We also see in Tables XI how probability of success varies with referral number. Probability of success definitely decreases when proceeding from the zeroeth to the first referral. Apparently, referred requests are more difficult to satisfy. Unfortunately, there is insufficient data to confidently conclude that the second and third referrals result in successively lower probabilities of success. This lack of data will be very evident once we break these probabilities down by request class. As noted earlier, the model could easily be adapted to utilize probabilities that are dependent on referral number. However, this will require either more data or fewer request classes.*

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*The choice of the number of subject and referral classes into which your data is partitioned depends on how you want to emphasize "subject sensitivity" and "referral sensitivity" in the network operating policies.

NETWORK SAMPLE

CENTER

	CPL	ISL	UOI	SIU	TOT
REFL. NO. 0					
TOTL. NO.	101	296	177	11	585
% AT 0	84.17	99.66	75.97	15.49	81.14
NO. FILD	46	270	133	5	454
NO. UNFILD	55	26	44	6	131
% FILD	45.54	91.22	75.14	45.45	77.61
REFL. NO. 1					
TOTL. NO.	9	0	44	34	87
% AT 1	7.50	0.00	18.88	47.89	12.07
NO. FILD	0	0	23	14	37
NO. UNFILD	9	0	21	20	50
% FILD	0.00	0.00	52.27	41.18	42.53
REFL. NO. 2					
TOTL. NO.	10	0	12	23	45
% AT 2	8.33	0.00	5.15	32.39	6.24
NO. FILD	0	0	3	0	3
NO. UNFILD	10	0	9	23	42
% FILD	0.00	0.00	25.00	0.00	6.67
REFL. NO. 3					
TOTL. NO.	0	1	0	3	4
% AT 3	0.00	0.34	0.00	4.23	0.55
NO. FILD	0	0	0	1	1
NO. UNFILD	0	1	0	2	3
% FILD	0.00	0.00	0.00	33.33	25.00
TOTALS					
TOTL. NO.	120	297	233	71	721
%	16.64	41.19	32.32	9.85	100.00
NO. FILD	46	270	159	20	495
NO. UNFILD	74	27	74	51	226
% FILD	38.33	90.91	68.24	28.17	68.65

TABLE XI A: Probability of Success as a Function of Center and Referral Number (Network Sample)

CENTER SAMPLE

	CENTER				
	CPL	ISL	UOI	SIU	TOT
REFL. NO. 0					
TOTL. NO.	97	332	264	71	764
% AT 0	59.88	96.51	82.24	32.72	73.18
NO. FILD	21	253	158	35	467
NO. UNFILD	76	79	106	36	297
% FILD	21.65	76.20	59.85	49.30	61.13
REFL. NO. 1					
TOTL. NO.	45	1	15	44	105
% AT 1	27.78	0.29	4.67	20.28	10.06
NO. FILD	6	0	7	8	21
NO. UNFILD	39	1	8	36	84
% FILD	13.33	0.00	46.67	18.18	20.00
REFL. NO. 2					
TOTL. NO.	12	8	32	58	110
% AT 2	7.41	2.33	9.97	26.73	10.54
NO. FILD	1	2	9	9	21
NO. UNFILD	11	6	23	49	89
% FILD	8.33	25.00	28.13	15.52	19.09
REFL. NO. 3					
TOTL. NO.	8	3	10	44	65
% AT 3	4.94	0.87	3.12	20.28	6.23
NO. FILD	1	0	2	5	8
NO. UNFILD	7	3	8	39	57
% FILD	12.50	0.00	20.00	11.36	12.31
TOTALS					
TOTL. NO.	162	344	321	217	1044
%	15.52	32.95	30.75	20.79	100.00
NO. FILD	29	255	176	57	517
NO. UNFILD	133	89	145	160	527
% FILD	17.90	74.13	54.83	26.27	49.52

TABLE XI B: Probability of Success as a Function of Center and Referral Number (Center Sample)

To overcome the scarcity of data, we decided to pool the two LRC samples within the 10 subject classes and not consider variations of probabilities with referral number. The pooling of these two data sets within subject classes requires that we assume that probability of success, within a given subject area, is not related to the type of library from which the request originated. Of the 1765 requests in both samples, 109 were without subject codes. Thus, our overall sample is 1656 which is divided among 4 Centers and 10 subject classes. Table XII shows the frequencies of success at each Center. For each category (i.e., call no., prev. ver., etc.), the left column represents the number of requests with that characteristic while the right column represents the number of requests without that characteristic. For example, for range 0 (000-099) at CPL, 8 requests were received all of which were without call numbers. 7 of the 8 had been previously verified. 4 were owned while 4 were not owned. Of the 4 owned, 1 was available while 3 were unavailable. The previously unverified request was not forwarded without an attempt at verification. However, it was not successfully verified.

Table XIII represents the same information but has been converted to probabilities. This table is very similar to the probabilities of success data file accessed by the model. To compare these parameters with ISL yearly statistics, we calculated probability of receipt with a call number, probability of ownership and probability of availability given ownership using ISL aggregate (across subject classes) statistics. This resulted in c_{ij} estimates or 0.01, 0.71, 0.11, and 0.03; o_{ij} estimates of 0.35, 0.91, 0.63, and 0.41; and a_{ij} estimates were 0.44, 0.86, 0.82, and 0.69 for CPL, ISL, UOI, and SIU, respectively. With the exception perhaps of the CPL o_{ij} estimate, the comparison is

FREQUENCIES OF SUCCESS FOR PROCESSING AT CPL

RANGE	CALL.NO.		PREV.VER.		OWNED		AVAILABLE		FORWARD		SUCC.VER.	
0	0	8	7	1	4	4	1	3	0	1	0	1
1	0	9	9	0	4	5	1	3	0	0	0	0
2	0	10	10	0	1	9	0	1	0	0	0	0
3	0	70	64	6	50	20	36	14	0	6	1	5
4	0	2	2	0	1	1	0	1	0	0	0	0
5	0	8	7	1	6	2	6	0	0	1	1	0
6	0	36	32	4	19	17	8	11	0	4	3	1
7	0	34	34	0	17	17	8	9	0	0	0	0
8	0	44	39	5	24	20	7	17	0	5	3	2
9	0	24	24	0	13	11	5	8	0	0	0	0
TOTALS	0	245	228	17	139	106	72	67	0	17	8	9

FREQUENCIES OF SUCCESS FOR PROCESSING AT ISL

RANGE	CALL.NO.		PREV.VER.		OWNED		AVAILABLE		FORWARD		SUCC.VER.	
0	14	7	19	2	21	0	18	3	0	2	2	0
1	31	6	38	1	37	2	26	9	0	1	0	1
2	29	5	33	1	33	1	31	2	0	1	1	0
3	87	54	130	11	130	11	121	9	0	11	8	3
4	1	2	1	2	2	1	2	0	0	2	1	1
5	13	5	17	1	18	0	16	2	0	1	1	0
6	55	35	81	9	80	10	69	11	1	8	7	1
7	49	22	65	6	65	6	54	11	0	6	4	2
8	98	18	114	2	111	5	100	11	0	2	2	0
9	66	31	93	4	89	8	82	7	0	4	4	0
TOTALS	443	167	591	39	586	44	521	65	1	38	30	8

FREQUENCIES OF SUCCESS FOR PROCESSING AT UOI

RANGE	CALL.NO.		PREV.VER.		OWNED		AVAILABLE		FORWARD		SUCC.VER.	
0	1	14	15	0	14	1	10	4	0	0	0	0
1	2	41	38	5	35	8	30	5	0	5	4	1
2	1	24	22	3	19	6	15	4	0	3	3	0
3	21	82	86	17	86	17	74	12	0	17	13	4
4	0	2	1	1	2	0	2	0	0	1	1	0
5	3	60	53	10	55	8	47	8	1	9	9	0
6	5	119	100	24	66	58	56	10	0	24	15	9
7	7	40	44	3	33	14	29	4	1	2	2	0
8	8	40	45	3	32	16	31	1	2	1	1	0
9	12	47	51	8	42	17	40	2	0	8	8	0
TOTALS	60	469	455	74	384	145	334	50	4	70	56	14

FREQUENCIES OF SUCCESS FOR PROCESSING AT SIU

RANGE	CALL.NO.		PREV.VER.		OWNED		AVAILABLE		FORWARD		SUCC.VER.	
0	0	2	2	0	2	0	1	1	0	0	0	0
1	0	22	21	1	13	9	10	3	0	1	0	1
2	0	18	16	2	5	13	4	1	0	2	0	2
3	0	62	56	6	38	24	21	17	0	6	2	4
4	0	0	0	0	0	0	0	0	0	0	0	0
5	0	6	6	0	3	3	3	0	0	0	0	0
6	0	52	48	4	18	34	12	6	0	4	2	2
7	0	37	36	1	15	22	10	5	0	1	1	0
8	0	20	20	0	9	11	8	1	0	0	0	0
9	0	33	30	3	10	23	7	3	0	3	3	0
TOTALS	0	252	235	17	113	139	76	37	0	17	8	9

TABLE XII: Frequencies of Success at Each Center

PROBABILITIES OF SUCCESS FOR PROCESSING AT CPL

RANGE	CIJ	VIJ	OIJ	AIJ	FIJ	SIJ
0	0,00	0,88	0,57	0,25	0,00	0,00
1	0,00	1,00	0,44	0,25	0,00	0,00
2	0,00	1,00	0,10	0,00	0,00	0,00
3	0,00	0,91	0,77	0,72	0,00	0,17
4	0,00	1,00	0,50	0,00	0,00	0,00
5	0,00	0,88	0,75	1,00	0,00	1,00
6	0,00	0,89	0,54	0,42	0,00	0,75
7	0,00	1,00	0,50	0,47	0,00	0,00
8	0,00	0,89	0,57	0,29	0,00	0,60
9	0,00	1,00	0,54	0,38	0,00	0,00
TOTAL	0,00	0,93	0,59	0,52	0,00	0,47

PROBABILITIES OF SUCCESS FOR PROCESSING AT ISL

RANGE	CIJ	VIJ	OIJ	AIJ	FIJ	SIJ
0	0,67	0,71	1,00	0,86	0,00	1,00
1	0,79	0,88	0,86	0,76	0,00	0,00
2	0,85	0,80	0,80	0,94	0,00	1,00
3	0,62	0,80	0,84	0,93	0,00	0,73
4	0,33	0,00	1,00	1,00	0,00	0,50
5	0,72	0,80	1,00	0,89	0,00	1,00
6	0,61	0,74	0,76	0,86	0,11	0,88
7	0,69	0,73	0,80	0,83	0,00	0,67
8	0,84	0,89	0,72	0,90	0,00	1,00
9	0,68	0,87	0,74	0,92	0,00	1,00
TOTAL	0,70	0,79	0,80	0,89	0,03	0,79

PROBABILITIES OF SUCCESS FOR PROCESSING AT UOI

RANGE	CIJ	VIJ	OIJ	AIJ	FIJ	SIJ
0	0,07	1,00	0,93	0,71	0,00	0,00
1	0,05	0,88	0,83	0,86	0,00	0,80
2	0,04	0,88	0,75	0,79	0,00	1,00
3	0,20	0,79	0,83	0,86	0,00	0,76
4	0,00	0,50	1,00	1,00	0,00	1,00
5	0,05	0,83	0,88	0,85	0,10	1,00
6	0,04	0,80	0,55	0,85	0,00	0,63
7	0,15	0,92	0,67	0,88	0,33	1,00
8	0,17	0,92	0,63	0,97	0,67	1,00
9	0,20	0,83	0,64	0,95	0,00	1,00
TOTAL	0,11	0,84	0,72	0,87	0,05	0,80

PROBABILITIES OF SUCCESS FOR PROCESSING AT SIU

RANGE	CIJ	VIJ	OIJ	AIJ	FIJ	SIJ
0	0,00	1,00	1,00	0,50	0,00	0,00
1	0,00	0,95	0,62	0,77	0,00	0,00
2	0,00	0,89	0,31	0,80	0,00	0,00
3	0,00	0,90	0,66	0,55	0,00	0,33
4	0,00	0,00	0,00	0,00	0,00	0,00
5	0,00	1,00	0,50	1,00	0,00	0,00
6	0,00	0,92	0,36	0,67	0,00	0,50
7	0,00	0,97	0,41	0,67	0,00	1,00
8	0,00	1,00	0,45	0,89	0,00	0,00
9	0,00	0,91	0,30	0,70	0,00	1,00
TOTAL	0,00	0,93	0,47	0,67	0,00	0,47

TABLE XIII: Probabilities of Success at Each Center

favorable. This partially justifies our necessary pooling the two LRC samples and may indicate that the reason for greater success in filling non-public library requests (noted earlier) is due to the subject distribution of those requests. In other words, within a subject area, probability of success is not related to originating library type. Thus, non-public libraries experience greater success because their requests are in subject areas for which documents are more likely to be owned and available. This last point is only conjecture.

PROCESSING TIMES

Now, we want to estimate the average processing time of a request at process k of Center i (denoted by a_{ik}). To approach this problem, we will first consider the overall processing times for satisfied and unsatisfied requests. These are shown in Table XIV. Note that unsatisfied requests at ISL and SIU require much more processing time than satisfied requests. On the other hand, unsatisfied requests at UOI require less processing time than satisfied requests. How can we explain this result?

	SATISFIED REQUESTS			UNSATISFIED REQUESTS		
CENTER	AVG.	STD. DEV.	N	AVE.	STD. DEV.	N
CPL	5.13	4.84	70	5.29	3.53	65
ISL	3.81	4.66	468	10.38	7.50	21
UOI	6.87	5.06	291	5.17	5.04	53
SIU	6.77	3.46	70	12.58	5.76	24

TABLE XIV: Overall Processing Times (in Days) at Each of the Centers

Recall our discussion of Center level processing in Project Report Nos. 1 and 2 (No. 1, pp. 20-27, No. 2 pp. 32-37). There we note that average overall processing time can be represented as a weighted linear sum of the average processing times in each of the six processes of a Center (ω_{i1}, ω_{i2}, ..., ω_{i6}). The weighting on ω_{ik} is 0 if the request did not utilize the k^{th} process, 1 if the request utilized the k^{th} process once, 2 if the request utilized the k^{th} process twice, etc. We know the overall processing time and the weightings from information collected in the LRC samples.* We want to estimate ω_{i1}, ω_{i2}, ..., ω_{i6}.

From the two LRC samples, we can form 1062 linear equations in six unknowns per Center.† Using an optimization technique to find the ω_{ik}'s that minimize the mean-squared error between the predicted overall processing times and the actual overall processing times we obtained the results in Table XV. The technique was constrained from producing any ω_{ik} less than 0.10 day. These results seem reasonable as the root-mean-squared (RMS) fitting errors are commensurate with the standard deviations in Table XIV. It should be stressed that these results are only valid as far as our data processing assumptions (in the Appendix) and the model of Center level processing (Report Nos. 1 and 2) are valid.

Considering some of the specific entries in Table XV, we see that ISL and SIU have large estimates for average time to forward an unsatisfied request. This is consistent with the results for overall processing times

*See the Appendix for assumptions necessary in processing this data.

†Of the 1765 requests represented in the two LRC samples, only 1062 had sufficient information (i.e., date entering and date leaving a Center) to be used in this analysis of processing times.

CENTER	IN-PROC	SEARCH	OBTAIN	OUT-PROC	VERIFY	FORWARD	N	RMS
CPL	4.42	0.10	0.10	0.46	0.92	0.68	135	4.22
ISL	3.05	1.80	0.10	0.13	4.84	6.26	489	4.66
UOI	2.32	1.45	0.10	3.14	0.10	1.34	344	5.20
SIU	2.34	3.22	0.10	0.94	3.14	6.85	94	4.06

TABLE XV:* Average Processing Times (in Days) for Each of the Six Processes at Each Center

noted above. The optimization technique estimates a large value for forwarding time because that is the only one of the six processes which unsatisfied requests exclusively employ.

On the other hand, UOI has a large estimate for time to out-process a document. The optimization technique estimates a large time for out-processing to account for increased overall processing time for satisfied requests. Intuitively, knowing the UOI campus and the geographical dispersion of its departmental libraries, one might expect that the obtain process would be the cause of increased processing time for satisfied requests. To pursue this possibility, we performed a more detailed analysis of within Center processing.

We started with three hypotheses.

1. Requests entering with call numbers and thus avoiding the search process, should have significantly less overall processing times than requests that must be searched.
2. Requests entering with previous verification and thus avoiding the verify process, should have significantly less overall processing times than requests that must be verified.

*The entries in this table should not be interpreted without reading pages in the text.

3. Requests for unowned documents which thereby avoid the obtain process, should have significantly less overall processing times than requests for unavailable documents that must go through the obtain process.

Testing the above three hypotheses* for each Center, we find hypothesis 1 supported for ISL and UOI while no other hypotheses were supported for any Center. In other words, the available data did not support the hypotheses that verification and obtaining are significant components of overall processing time. This does not mean that these processes do not in fact consume significant amounts of time, but only that the data was insufficient to prove it.

More specifically the verification hypothesis is subject to much statistical error due to the great ambiguity of responses on the questionnaire forms (see Appendix). The obtain hypothesis was tested using very small samples. This was due to the fact the date information was not filled in for many unsatisfied requests and we can only look at the impact of the obtain process on unsatisfied requests. (All satisfied requests go through the obtain process.)

Thus, the average processing times for obtain and verify are not of much use and should be interpreted accordingly. For example, we cannot use this data to predict the impact of computerized circulation systems on network performance because one of the main benefits of such a system is the avoidance of the obtain process unless the document is available and we have little or no faith in the estimates in Table XV that indicate how much processing time might be saved.

*More formally, we used a t-test to test the hypothesis that significant differences did not exist. Hypotheses were rejected when the significance level was $\leq .05$.

Another point is also important. Since all satisfied requests are processed at in-process and at out-process, we cannot separate the average amount of time devoted to each process. Similarly, since all unsatisfied requests are processed at in-process and at forward, we cannot separate the average time devoted to each of these processes. When using the non-queueing option of the ILLINET model, this difficulty has absolutely no effect on model predictions. However, with the queueing option, it does add an unknown for which we have no information. Thus, we will not utilize the queueing option in later analyses to be discussed in this report. In the future, different data collection procedures may avoid this problem.

As a final comment on the estimates of processing time discussed here, we should note that weekend days are included in the processing time estimates. Thus, the results do not necessarily represent continued active processing of a request and may include periods when the interlibrary loan effort is closed down. We could adjust the LRC data to exclude weekends, but it seems more appropriate to retain the time estimates that the requestor actually endures.

DELIVERY TIMES

To estimate t_{ik} (the average postal delivery time to System k from Center i), we will use data from the previously noted ISL postal delivery time study. While this data only includes average delivery times from ISL to various Systems, we will assume that this data is typical of postal service throughout Illinois.

One would imagine that postal delivery times are related in some way to distance. To estimate the distances between Centers and Systems, we assume Systems to be in the geographical center of the region they represent and then measured the straight-line distances between points.* Plotting the ISL delivery time data versus distance, we reached two conclusions. First, average delivery time is roughly a linear function of distance (i.e., $t_{ik} = a + bd_{ik}$ where d_{ik} is the distance between Center i and System k while a and b are constants). Second, the linear function is different if a metropolitan area (Chicago or St. Louis) is involved.

Based on these conclusions, we employed a weighted-least-squared-error fitting method (weighted by the number of data points in each estimate of average delivery time) to obtain the following results. For deliveries involving metropolitan areas, we found $t_{ik} = 0.85 + 1.13\ d_{ik}$ (where the units of d_{ik} are hundreds of miles) with a root-mean-squared fitting error of 0.200 days. Similarly, for deliveries involving only non-metropolitan areas we found $t_{ik} = 0.97 + 0.29\ d_{ik}$ with a root-mean-squared fitting error of 0.157 days.

Using these two linear functions to estimate average delivery times between all Centers and Systems, the results in Table XVI were obtained. To estimate the average delivery time for large academic libraries

*While Systems are not necessarily in the geographical centers of their regions, a more exact knowledge of their location is not necessary in light of the less tenable assumption that straight-line distances are appropriate. However, we have no practical alternative but to use this straight-line assumption and, since we are only estimating average delivery times, the accuracy of our estimates is probably not substantially affected by this approximation.

	CENTER			
SYSTEM	CPL	TSL	UOI	STU
BO	1.4	2.5	1.9	4.1
CP	1.0	2.9	2.3	4.5
CB	2.2	1.2	1.1	1.6
CT	3.6	1.3	1.3	1.2
DU	1.2	2.9	2.4	4.5
GR	3.4	1.2	1.4	1.5
IV	2.4	1.2	1.2	1.6
KK	4.1	2.1	2.6	1.6
LA*	2.0	1.9	1.8	2.7
LC	3.6	1.5	2.2	2.1
LT	2.4	1.3	1.0	1.6
NS	1.2	3.2	2.7	4.8
NI	1.8	1.5	1.4	1.9
RB	2.4	1.4	1.4	1.8
RP	2.9	1.1	1.1	1.4
SH	4.5	1.5	1.5	1.1
SR	1.9	1.3	1.3	1.8
SU	1.1	1.5	1.3	1.9
WI	2.9	1.9	2.5	3.6

*Large Academic Libraries

TABLE XVI: Average Postal Delivery Times (in Days) Between Centers and Systems

(our 19th System), we used a weighted average of the average delivery times for all other Systems where the weighting on the k^{th} System's average delivery time was the percent of overall demand generated by that System.

SUMMARY

Tables XA, XIII, XV, AND XVI include the desired model parameters. We will now proceed to discuss using the ILLINET model and the implications of various network operating policies. However, before continuing, a word of caution is appropriate. The model parameters which we have obtained represent the state of the network in 1974-1975 as best we could determine it with available data. Parameters will certainly vary in the future as demand levels change and new technology is implemented. Thus, the parameters tabulated in this report should not be maintained as necessarily the "true" parameters. Data collection will have to continue and parameter values updated. This section of our report indicates what data is of interest. We hope in the future to be able to describe a rigorous and systematic method of data collection that will enable monitoring of the model and updating of parameters.

III. POLICY ANALYSES

A. INTRODUCTION

The purpose of this section is to illustrate the effects (on network performance) of several classes of request routing policies. We will first consider a class of policies that emphasize maximization of probability of success without regard to average delay from initiation of a request until receipt of the desired item by the requesting System. Next, a class of policies that emphasize minimization of average delay will be discussed. Then, we will consider a class of policies that tradeoff probability of success and average delay. The meaning and possibility of optimal request routing policies are then discussed and finally, some specific recommendations are summarized and evaluated.

As we have pursued these analyses, it has become increasingly evident that our sample sizes are inadequate for the type of analyses that we are developing. For example, several of the percentages in Table XIII are based on data from two requests. Nevertheless, management decisions still must be made and one has no choice but to employ whatever data is available. However, the reader should keep in mind that results discussed in this section should be viewed mainly as interesting possibilities which require further data for complete justification.

B. POLICIES THAT EMPHASIZE MAXIMIZATION OF PROBABILITY OF SUCCESS

An intuitively appealing routing policy is to simply send requests to the libraries most likely to satisfy them. This approach may be unsatisfactory if, for example, the library most likely to satisfy your request is distant in delivery time (e.g., New York Public Library) while a local library (e.g., Champaign Public Library) may have a slightly lower probability of

success but can satisfy your request in 30 minutes if the item is owned and available. Disregarding this limitation, we will now consider the network performance resulting with policies that emphasize probability of success.

The policy is simple. Within each subject class, order the four Centers (CPL, ISL, UOI, and SIU) by decreasing P_{ij} and refer requests in that order until satisfied or a constraint is met (such as a budget limitation, which we did not consider). For this class of policies, all Systems would utilize the same policy within any given subject class. Using these policies, the ILLINET Model produced the results shown in Table XVII.

As policies allow more referrals, we see that probability of success increases as does average delay and cost. An interesting numeric is the marginal unit cost of referral which can be defined as

$$\text{marginal unit cost} = \frac{\text{increased total cost due to referral}}{\text{increased no. of satisfied requests due to referral}} \quad (1)$$

Using this definition of marginal unit cost, we find that the first referral yields a cost of $3.25 per satisfied request, the second referral yields a cost of $4.48 per satisfied request, and the third referral results in a cost of $5.78 per satisfied request. Thus, we see that unit cost only increases modestly with number of referrals while marginal unit cost increases vary substantially. This is simply due to the fact that the referral Centers (usually CPL and SIU) do not perform as well (in terms of probability of success) as the initial Centers (usually ISL and UOI).

C. POLICIES THAT EMPHASIZE MINIMIZATION OF AVERAGE DELAY

Instead of maximizing probability of success, we might choose a routing policy that yields the minimum average delay. Then, the requestor will receive the desired item relatively quickly if his request is satisfied. Of

PERFORMANCE MEASURE	NUMBER OF REFERRALS			
	0	1	2	3
INPUT DEMAND PER DAY*	860	860	860	860
TOTAL DEMAND PER DAY	860	1014	1072	1110
NO. SATISFIED PER DAY	706	801	820	829
NO. UNSATISFIED PER DAY	154	212	252	282
PERCENT SATISFIED	82.1	93.2	95.4	96.4
AVERAGE DELAY (IN DAYS)	5.92	7.58	7.98	8.27
TOTAL COST PER DAY	1071	1380	1465	1517
COST PER SATISFIED REQUEST	1.52	1.72	1.79	1.83

*250 days of operation per year is assumed.

TABLE XVII: Network Performance With Policies That Emphasize Maximization of Probability of Success

course, the difficulty with this policy is that the library which performs well in terms of average delay may not perform well in terms of probability of success. This problem can be partially avoided by defining average delay for a library as

average delay = probability of success x average delay for satisfied requests + probability of failure x average delay for unsatisfied requests (2)

where probability of success is the P_{ij} defined in section II-B, probability of failure is $1-P_{ij}$, and the average delays for satisfied and unsatisfied requests are found in Table XIV.

To define a route, proceed as follows. Within each subject class, order the four Centers by increasing average delay as defined in (2), and refer requests in that order until satisfied or a constraint is met. For this class of policies, all Systems will not employ the same policy within a given subject class. Instead, for a given System and subject class, we calculate the average delay experienced by the System (utilizing the appropriate delivery times from Table XVI) for each alternative route and choose the route with minimal average delay.* Thus, each System has a choice of four possible routes for each subject classes. (Each of the four alternatives represents initiation at one of the four Centers and referrals chosen by equation (2)).

Using this approach to policy formulation, the results in Table XVIII were obtained. Comparing Tables XVII and XVIII, we see that those policies in Table XVII are clearly preferable except when there is one referral. With one referral, the policy in Table XVIII results in less average delay, approximately the same unit cost, and lower probability of success than obtained with the policy in Table XVII. The particular policy preferred for one referral

*This computation is performed utilizing equations 1 through 5 in the Appendix of Project Report No. 2, pp. 27-30.

PERFORMANCE MEASURE	NUMBER OF REFERRALS			
	0	1	2	3
INPUT DEMAND PER DAY*	860	860	860	860
TOTAL DEMAND PER DAY	860	1014	1126	1170
NO. SATISFIED PER DAY	291	749	816	829
NO. UNSATISFIED PER DAY	569	266	310	340
PERCENT SATISFIED	33.9	87.1	94.9	96.4
AVERAGE DELAY (IN DAYS)	6.34	6.63	8.17	8.54
TOTAL COST PER DAY	1160	1293	1516	1579
COST PER SATISFIED REQUEST	3.98	1.73	1.86	1.90

*250 days of operation per year is assumed.

TABLE XVIII: Network Performance With Policies That Emphasize Minimization of Average Delay

depends on a value judgement concerning a tradeoff between probability of success and average delay.

In general, policies that emphasize minimization of average delay are not acceptable for a small number of referrals (especially zero) because CPL is closest (in terms of delivery time) to a great amount of request demand but is not as capable of satisfying that demand as ISL or UOI. However, with a larger number of referrals, policies that emphasize minimization of average delay might be appropriate if resources do not differ greatly in probability of success. For example, if Systems have a reasonably high probability of satisfying a request within the System, they can avoid sending requests to the Center level of the network and lessen average delay over what would be obtained by using the Centers. In fact, it appears that Systems use a policy somewhat like this now. However, we want to emphasize that such a policy is not always preferrable as evidenced by the results in Table XVIII.

D. POLICIES THAT TRADEOFF PROBABILITY OF SUCCESS AND AVERAGE DELAY

Now, we want to consider policies that emphasize both probability of success and average delay. Let us define the value of an alternative request routing policy as

$$\text{value of a policy} = \frac{\text{probability of success}}{\text{average delay}}. \tag{3}$$

This definition of value is somewhat like a benefit-to-cost ratio, but is by no means anything other than an intuitively chosen definition. Various alternative definitions of value could be employed and the difficulty is choosing the appropriate definition. Nevertheless, we will proceed to consider policies that emphasize maximization of value as defined in (3).

Policies are formed, within a subject class, by ordering the four Centers by decreasing value and then referring requests in that order until a constraint is met. For each System and subject class, the value of each alternative route is calculated and the System initiates its requests at the Center whose associated route has the highest value to that System. Since this includes delivery time estimates, the Systems will not all initiate their requests at the same Center.

The results shown in Table XIX were obtained with this policy. These results are almost identical to those in Table XVII. The reason is simply that ISL and, to a lesser extent UOI, dominate the network in terms of our three performance measures. ISL has the highest probability of success, the smallest average delay for satisfied requests, and the lowest processing costs since its filmed catalog allows the searching cost to be avoided. The only undesirable aspect of ISL is the large average delay for unsatisfied requests. We will return to some of these points later in our discussion.

E. THE POSSIBILITY OF OPTIMAL POLICIES

In the previous sections, we considered three alternative approaches to policy formulation. A question that arises naturally from this discussion is: What is the best or optimal policy? Optimality can only be defined with respect to some criterion. In Project Report No. 1, we defined an appropriate criterion for interlibrary loan networks to be maximization of service within any cost constraints. Then we proceeded to define service as having two components; probability of success and average delay. However, this definition is insufficient since we must have some way of deciding whether or not, for example, an increase in probability of success via referral is worth the increased average delay due to increased processing loads that result in larger request queues.

PERFORMANCE MEASURE	NUMBER OF REFERRALS			
	0	1	2	3
INPUT DEMAND PER DAY*	860	860	860	860
TOTAL DEMAND PER DAY	860	1014	1073	1113
NO. SATISFIED PER DAY	706	801	820	829
NO. UNSATISFIED PER DAY	154	213	253	284
PERCENT SATISFIED	82.0	93.2	95.3	96.4
AVERAGE DELAY (IN DAYS)	5.92	7.57	7.94	8.23
TOTAL COST PER DAY	1076	1384	1470	1525
COST PER SATISFIED REQUEST	1.52	1.73	1.79	1.84

*250 days of operation per year is assumed.

TABLE XIX: Network Performance With Policies That Tradeoff Probability of Success and Average Delay

Perhaps the policy value measure given in (3) is appropriate. Before such a choice is made, one should invest some time into thinking about such performance measures. If a choice can appropriately be made, then the resulting optimization problem (i.e., Maximize the criterion value = ... subject to the constraints that...) may be amenable to one or more of the various optimization methodologies. We have looked briefly at two variations of dynamic programming formulations and they appear to be applicable to several tenable policy performance measures. The development of these approaches might be an interesting effort to pursue in the future.

F. DISCUSSION

What conclusions can be drawn from our analyses? Keeping in mind the paucity of the data, it is safe to say that the Centers of first resort should be ISL and UOI. The superiority of their performance over that of CPL and SIU is clear. Why does this occur? One intuitively pleasing reason might be the availability of ISL and UOI filmed catalogs. However, the results in Table XIII do not support this idea. ISL has a 0.80 overall probability of ownership for those requests received without call numbers. (We assume that these requests were not affected by the availability of the film catalog.) UOI has a 0.72 probability of ownership (for requests without call numbers) while the probability of ownership is 0.59 for CPL and 0.47 for SIU. The lower probabilities of ownership for CPL and SIU might be explained by the fact that many requests received by those Centers are referrals and thus, may be more difficult to satisfy. However, the results in Tables XI show that CPL and SIU have low probabilities of success for those requests which they receive directly from the Systems. Considering Table XIII, we see that the difficulty at CPL is mainly availability with only 52% of owned items

being available. This is not surprising when we consider that CPL is the only public library that serves as a Center in a network where most of the demand is from public libraries. Thus, the local clientele of CPL is using the same type of items that the network clientele desires. On the other hand, SIU seems to suffer from both a weaker collection (relative to the other Centers) and somewhat of an availability problem. Perhaps its local clientele is less research oriented than that at UOI.

What would be the impact of removing CPL and/or SIU from the network? The results of such an analysis are shown in Tables XX through XXII.* Comparing these results with those in Table XIX, we see that removal of CPL or SIU makes little difference. Removal of Both CPL and SIU only makes a difference for requests that are referred more than once. Currently, this occurs with approximately 15% of requests (Table XIB) and, even for those requests, the degradation of service would be minor. From these analyses, we conclude that the removal of both CPL and SIU should be seriously considered. However, this conclusion is based on limited data and effort should be invested into gathering sufficient data to make this decision soundly.

In general, all of the results presented here must be looked upon as tentative. The data simply does not allow specific recommendations that can be defended statistically. The next priority should be the development of data collection procedures that will yield sufficient data to allow strong recommendations.

*The approach to policy formulation discussed in section III-D was employed (i.e., maximum value).

PERFORMANCE MEASURE	NUMBER OF REFERRALS		
	0	1	2
INPUT DEMAND PER DAY*	860	860	860
TOTAL DEMAND PER DAY	860	1014	1072
NO. SATISFIED PER DAY	706	801	819
NO. UNSATISFIED PER DAY	154	212	253
PERCENT SATISFIED	82.1	93.2	95.2
AVERAGE DELAY (IN DAYS)	5.92	7.58	7.97
TOTAL COST PER DAY	1071	1381	1465
COST PER SATISFIED REQUEST	1.52	1.72	1.79

*250 days of operation per year is assumed.

TABLE XX: Network Performance Without CPL

PERFORMANCE MEASURE	NUMBER OF REFERRALS		
	0	1	2
INPUT DEMAND PER DAY*	860	860	860
TOTAL DEMAND PER DAY	860	1014	1073
NO. SATISFIED PER DAY	706	801	817
NO. UNSATISFIED PER DAY	154	213	256
PERCENT SATISFIED	82.0	93.2	94.9
AVERAGE DELAY (IN DAYS)	5.92	7.57	7.88
TOTAL COST PER DAY	1076	1385	1466
COST PER SATISFIED REQUEST	1.52	1.73	1.80

*250 days of operation per year is assumed.

TABLE XXI: Network Performance Without SIU

PERFORMANCE MEASURE	NUMBER OF REFERRALS	
	0	1
INPUT DEMAND PER DAY*	860	860
TOTAL DEMAND PER DAY	860	1014
NO. SATISFIED PER DAY	706	801
NO. UNSATISFIED PER DAY	154	212
PERCENT SATISFIED	82.1	93.2
AVERAGE DELAY (IN DAYS)	5.92	7.58
TOTAL COST PER DAY	1071	1381
COST PER SATISFIED REQUEST	1.52	1.72

*250 days of operation per year is assumed

TABLE XXII: Network Performance Without CPL and SIU

APPENDIX

ASSUMPTIONS IN PROCESSING THE LRC SAMPLES

A. INTRODUCTION

Various assumptions and manipulations of the raw data were necessary in order to obtain the necessary data for the model. In this Appendix, we will detail these assumptions and note how they differ for the two LRC samples. As in earlier sections of this report, we denote the LRC samples as network sample and center sample.

B. VERIFICATION AND CALL NUMBER DATA

Verification data was used to determine whether or not time was spent by the Center in verifying the request and whether or not they were successful in verification. The model for intra-library processing assumes that if a Center successfully verified a request, they would re-search the request in their catalog. If the Center was unsuccessful in verifying the request, they would necessarily forward the request to another Center or back to the requesting System.

Two types of data from LRC's samples are used to determine whether or not time was spent in the verification process, if verification was successful, and if a call number was previously provided.

To determine whether or not time was spent in the verification process, we used the data coded for "verification accuracy." If a Center indicated "1-verif. and acc.," we assumed the request was previously verified, and the Center receiving the request did not spend time verifying. In general, any other code indicating "verification accuracy" (e.g., "2-verif. and inacc.," "3-unverif., verif. at R & R," or "4-unverif., not able") meant that the Center receiving the request spent time in the verification process.

A brief note appears necessary regarding our interpretation of the code "4-unverif., not able," which was only used in the network sample. We assumed this code was indicated by a Center which spent time verifying a request but was unsuccessful. Because "unverif., not able" is ambiguous with respect to time spent verifying, we discussed our assumption with the Director of the U. of I. Illinois Interlibrary Borrowing Office. She confirmed our assumption that most Centers try to verify but felt that if we found many requests with this verification status, our assumption is probably wrong indicating the Center did not try to verify. Since we found only four requests with this verification status, we feel our interpretation of this data is reasonable.

To determine whether or not a Center was successful in verifying a request we used the data coded for "verification tool." We assumed that any code entered meant the Center was successful in verifying the request.

Distribution for verification accuracy and verification tool codes are given in Table A1. From Table A1, the data indicates that for CPL (combined sample) 266 requests were coded "1-verif. and acc." We interpret this data to mean that CPL did not try to verify 266 requests. However, we find that CPL coded a verification tool for 267 requests (284 - 17 = 267) which according to our assumption indicates 267 requests were successfully verified. In other words, 266 requests were previously verified and successfully re-verified at CPL. This general trend can be illustrated in Table A1 for the other Centers.

CPL

Ver. Acc.	No. Fill	No. No Fill	Total
1	70	196	266
2	1	1	1
3	4	8	12
4	0	4	4
No Code	0	0	0
Total	75	209	284

Ver. Tool	No. Fill	No. No Fill	Total
1	12	138	150
2	0	0	0
3	36	3	39
4	0	7	7
5	5	17	22
6	0	1	1
7	1	9	10
8	0	1	1
9	17	20	37
No Code	4	13	17
Total	75	209	284

No. without fill code = 0

ISL

Ver. Acc.	No. Fill	No. No Fill	Total
1	501	99	600
2	2	0	2
3	5	9	14
4	2	2	4
No Code	8	1	9
Total	525	113	638

Ver. Tool	No. Fill	No. No Fill	Total
1	30	27	57
2	0	0	0
3	4	0	4
4	2	1	3
5	2	5	7
6	6	2	8
7	391	55	446
8	0	0	0
9	47	9	56
No Code	43	14	57
Total	525	113	638

No. without fill code = 3

UOI

Ver. Acc.	No. Fill	No. No Fill	Total
1	291	188	479
2	5	4	9
3	27	11	38
4	9	8	17
No Code	3	0	3
Total	336	214	550

Ver. Tool	No. Fill	No. No Fill	Total
1	69	98	167
2	0	1	1
3	3	0	3
4	9	8	17
5	41	21	62
6	6	4	10
7	6	7	13
8	52	10	62
9	113	45	158
No Code	37	20	57
Total	336	214	550

No. without fill code = 5

SIU

Ver. Acc.	No. Fill	No. No Fill	Total
1	71	196	267
2	0	0	0
3	5	9	14
4	0	3	3
No Code	1	0	1
Total	77	208	285

Ver. Tool	No. Fill	No. No Fill	Total
1	26	124	150
2	0	0	0
3	0	0	0
4	1	5	6
5	10	22	32
6	4	3	7
7	3	13	16
8	1	3	4
9	26	26	52
No Code	6	12	18
Total	77	208	285

No. without fill code = 3
No. without Center code = 0

Table A-1. Verification Information

After looking at some yearly statistics from ISL we realized that our assumptions needed revising. In particular, ISL and UOI claimed to receive 71% and 11% of their requests with previously provided call numbers. We decided to assume that if a Center indicated "1-verif. and acc." for "verification accuracy" we ignored any data coded for "verification tool," and assumed the Center did not spend time verifying the request.

The one exception to this assumption arises in the determination of whether or not a call number was previously provided. In this case, we used the data coded for "verification tool." The model for intra-library processing assumes that if a call number is previously provided, the Center receiving the request does not spend time in the search process, i.e., a main catalog search, not a shelf-list search.

Because ISL and UOI are the only Centers with holdings tools indicated by the "verification tool" data we can expect that only these Centers will possibly bypass the search process. CPL and SIU will enter the search process for every request they receive because the data does not indicate whether or not a call number was previously provided for those Centers.

In the case for requests received by ISL and UOI, we assumed the request was provided with a call number if ISL or UOI indicated the "verification tool" for their respective holdings, i.e., a code of "7" or "8" respectively. Processing the data for Table XIII (see text) we see that the following probabilities indicate the percent of requests entering the

Center with previously provided call numbers: CPL - 0.00 (0.01), ISL - 0.70 (0.71), UOI - 0.11 (0.11), and SIU - 0.00 (0.03). The probabilities in parentheses are from ISL's yearly statistics which are closely predicted by the sample data using the appropriate assumptions.

All of the assumptions outlined in this section apply to both network and center samples.

C. OBTAIN AND OUT-PROCESS DOCUMENT

If a request was indicated "filled" by the Center, we assume the Center obtained the document and out-processed the document for delivery. This data was interpreted the same way for both network and center samples.

D. OUT-PROCESS, NO FILL

For requests not filled, we assume the Center owned the document but that it was not available if the Center indicated "2 = in circ.," "3 = non circ.," "4 - on order/in process," "5 = would send, not available," or "7 = NWA too near." We assumed a request was not owned by a Center if they indicated "1 = not owned," "6 = citation unusable," or "8 = inappropriate." Interpretations about whether an item was owned or not owned were made independent of verification data and based solely on "fill/no fill" status and "reason for no fill" data. Interpretation of the data is the same for both network and center samples.

E. PROCESSING TIME AND REFERRAL ORDER

For the network sample we converted dates to Julian days and have included weekends and holidays. Therefore processing times may appear longer than actual time in process at the library or subnodes.

Referral order is implied by the dates and if referral order data does not correspond with Julian date order, we assume the referral order was incorrectly entered and use the Julian day for ordering referrals.

If a referred request has no date-out indicated, we assume the date-out from the Center is equal to the date-in of the next Referral Center. Similarly, if no date-in is indicated for a zeroeth Referral Center, we assume the date-in of the zeroeth Referral equal to the date-out of the allocating System.

If no date-out is indicated for the last Referral Center, we then have no data on overall processing time for that request. We could perhaps calculate an average processing time for that Center (based on the complete data) and find an estimated Julian day for date-out.

Since Julian days were entered in the Center sample and request history data was not available, we did not have to manipulate the referral order or date [illegible]. If no referral number was indicated for a request in this sample, we assumed the request was a direct request.